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SOUTHWEST RESEARCH INST SAN ANTONIO TEX ARMY FUELS A--ETC F/8 11/8  
INSPECTION OF POLICE CRUISER ENGINES OPERATED USING RE-REFINED --ETC(U)  
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# INSPECTION OF POLICE CRUISER ENGINES OPERATED USING RE-REFINED AND VIRGIN BASED CRANKCASE LUBRICANTS

INTERIM REPORT

AFLRL NO. 92

by

Edwin A. Frame

Prepared by

U.S. Army Fuels and Lubricants Research Laboratory  
Southwest Research Institute

San Antonio, Texas

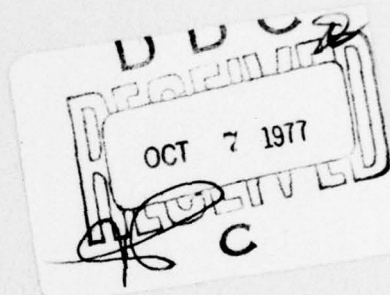
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# INSPECTION OF POLICE CRUISER ENGINES OPERATED USING RE-REFINED AND VIRGIN BASED CRANKCASE LUBRICANTS

## Introduction

As part of the joint EPA/DoD Rerefined Engine Oils Program, an inspection was made of the engines from six police cruisers from the city of San Diego, CA (SD) which operated for approximately three years on rerefined engine oil. The engines were disassembled and rated for deposits using standard CRC rating techniques. To provide a general reference framework, two police cruisers with the same engine type from Hollywood Park, TX (HP) which had been operated on virgin base oil were inspected and rated.

## San Diego, CA Inspection

The city of San Diego, CA operated on rerefined engine oil from about February 1974 until early 1977. A sample of the rerefined engine oil used by the police department was obtained from SD and analyzed. The physical property/chemical analyses showed the lube to have properties typical of "conventional" virgin based lubricants. Table 1 shows the inspection data for rerefined engine oil AL-6542 (Police Sta) was used during the bulk of the mileage accumulation. Arrangements were made with Center City Ford of SD to have them disassemble the engines from six SD police cruisers as they were being traded in. The vehicles were 1974 Ford Torino four-door sedans equipped with 351 CID Cleveland block engines and automatic transmissions. The vehicles were *not* equipped with air-conditioning. Complete maintenance records of the inspected vehicles were obtained from the SD police. Both oil and oil filter were changed at 4,000 mile intervals. The units had accumulated between 88,000 and 110,000 miles.

The summarized deposit ratings for varnish, sludge, rust, and intake valves are presented in Table 2. Overall, the engines had light sludge, very light rust and moderate varnish deposits. The ratings of individual engine parts are presented in Appendix A. Figure 1 shows a representative piston and a valve lifter from SD unit #730. In early 1977, SD switched to a virgin based lubricant, apparently because of a lower bid price. Table 3 shows the used crankcase oil analyses from SD unit #723, which is probably the virgin based oil.

## Hollywood Park, TX Inspection

Two 1974 Ford Torino four-door sedan, police cruisers equipped with 351 CID Cleveland block engines, automatic transmissions and air-conditioning were made available for inspection by the city of Hollywood Park, TX (HP). The HP police chief assured



Table 1.  
Rerefined Engine Oil - San Diego Fleet

<u>Description:</u>		<u>Police Sta</u>
AL #		6542
<u>Properties:</u>	<u>ASTM Method</u>	
Kinematic Viscosity, 38°C, cS	D445	122.94
Kinematic Viscosity, 99°C, cS	D445	14.98
Viscosity Index	D2270	130
API Gravity, °	D287	27.0
Flash Point, °C(°F)	D92	218(424)
Pour Point, °C(°F)	D97	-25(-15)
Ramsbottom Carbon Residue, %w	D524	0.87
Total Acid No.	D664	2.10
Total Base No.	D2896	5.83
ASTM Color	D1500	6.0
Sulfated Ash, %w	D874	0.78
Sulfur, %w	XRF	0.46
Phosphorus, %w	XRF	0.106
Cl, %w	XRF	0.0175
Ca, %w	XRF	0.20
Zn, %w	XRF	0.11
Iron, ppm	AA	< 1
Lead, ppm	AA	< 1

---

XRF = X-Ray Fluorescence.  
AA = Atomic Absorption.



Table 2.  
1974 FORD TORINOS  
SAN DIEGO, CA POLICE CRUISERS<sup>a</sup>  
OPERATED ON REREFINED ENGINE OILS<sup>a</sup>

SDPD Unit No.	Veh. ID No.	Eng. Type	Manuf. Date	Odometer Miles	Avg. Deposit Ratings, Merits				Int. Valves
					Varnish		Sludge Engine	Rust Lifters	
					Pistons	Engine			
701	4H27H178785	351C	3-74	96,590	5.7	7.0	9.3	9.8	7.8
712	4H27H178853	351C	3-74	91,328	6.3	6.8	9.5	9.8	8.0
723	4H27H178864	351C	3-74	109,703	6.4	5.7	9.2	9.8	9.4 <sup>b</sup>
730	4H27H178851	351C	3-74	104,514	6.3	6.3	9.3	9.8	8.1
764	4H27H178820	351C	3-74	88,267	6.3	6.8	9.3	9.8	9.2
742	4H27H178798	351C	3-74	91,395	6.0	6.2	9.3	9.8	8.1

1974 FORD TORINOS  
HOLLYWOOD PARK, TX POLICE CRUISERS  
VIRGIN BASE ENGINE OILS<sup>c</sup>

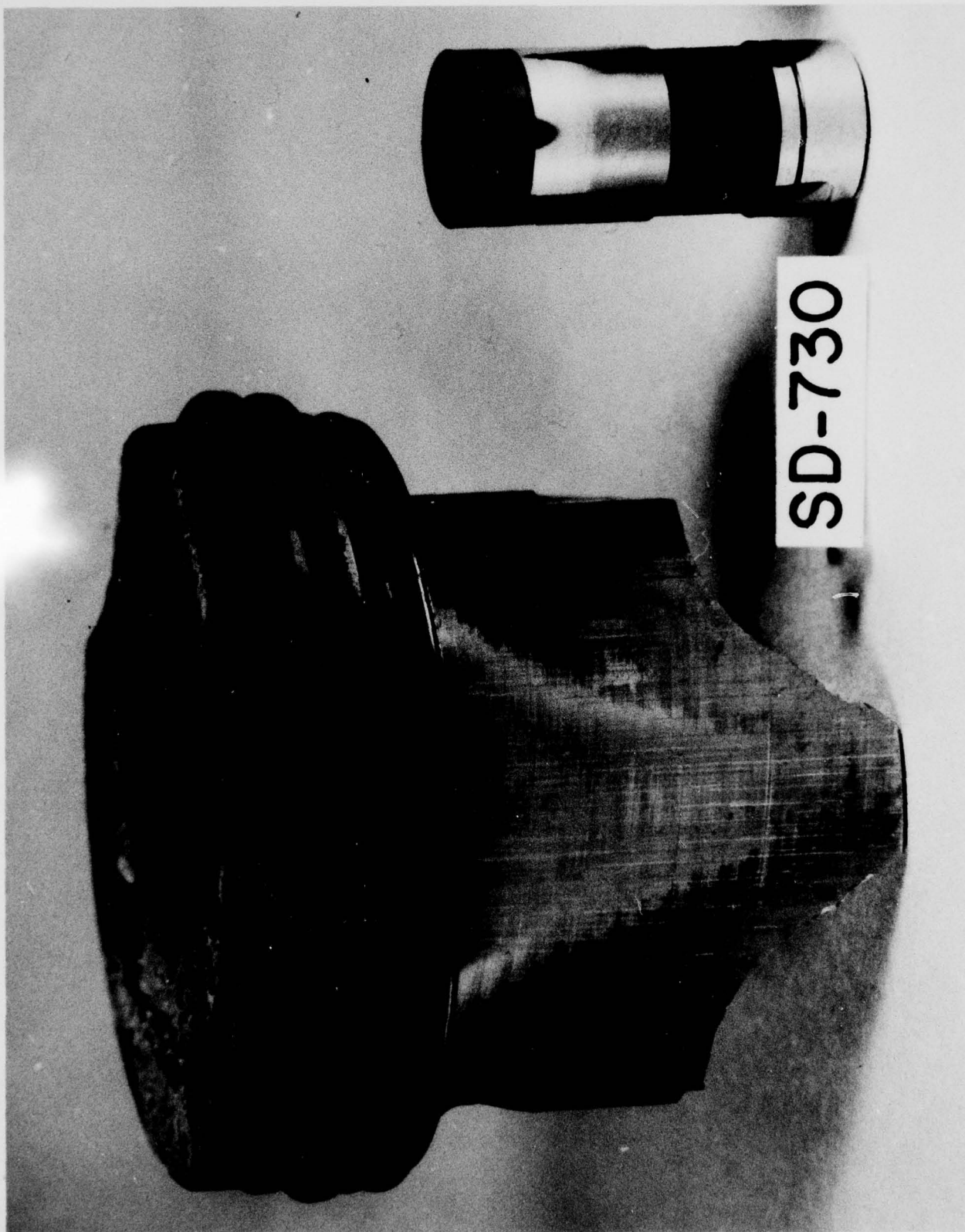
HPPD Unit No.	Veh. ID No.	Eng. Type	Manuf. Date	Odometer Miles	Avg. Deposit Ratings, Merits				Int. Valves
					Varnish		Sludge	Rust	
					Pistons	Engine	Engine	Lifters	
45	4H27Q223208	351C	7-74	65,488	6.6	4.3	8.6	9.0	8.0
44	4H27Q223207	351C	7-74	71,847	6.0	4.6	8.7	8.8	8.7

a - Oil and filter changed at 4,000 mi. intervals.

b - Recond. heads @ 84,664, 5/76.

c - Oil and filter changed at 6,000 mi. intervals.

Deposit ratings made in accordance with standard CRC techniques where 10 = clean.



SD-730

Table 3.  
Used Oil Analyses

<u>Property</u>	<u>Test Method</u>	<u>San Diego Unit #723</u>	<u>Hollywood Park Unit #45</u>
Viscosity, 38C, cS	D445	104.03	173.60
Viscosity, 99C, cS	D445	13.38	15.78
Viscosity Index	D2270	135	101
Sulfated Ash	D874	1.69	3.26
Elements, ppm	XRF <sup>a</sup>		
Ca		1300	700
Zn		800	350
Cu		NIL	200
Fe		35	275
Cl		1330	4200
Br		Present	Present
Al		NIL	>1000
Pb		>3000	>6000

---

a = XRF = X-Ray Fluorescence.



AFLRL that the vehicles had used only conventional (i.e., virgin based) engine oils. Both the oil and oil filter were changed at 6,000 mile intervals by a local service station who stated that premium, multigrade, SE service classification lubricant was used. Recently HP started doing their own oil changes using a bulk supply lubricant. The supplier of this lubricant was contacted and stated that he was supplying a commercial, SAE 30 grade, SE service classification lubricant. The vehicles were disassembled and rated at Southwest Research Institute, San Antonio, Texas. The deposit ratings for both the SD and HP engines were made by the same individual.

The summarized deposit ratings for the HP units are also shown in Table 2, with the individual engine part ratings presented in Appendix B. In addition to rather heavy engine varnish (especially on the valve lifters), the HP units had medium to heavy wear on the main and connecting rod bearings and the valve lifters were slightly dished. Figure 2 shows a representative piston and a valve lifter from HP unit #44. Analyses of the used crankcase oil from HP unit #45 are shown in Table 3. The relatively low calcium and zinc levels of this used oil are an unexplained inconsistency with respect to the use of SE quality oil. The presence of bromine and the high lead and chlorine contents indicate that both fleets used leaded gasoline.

#### Summary/Conclusion

The SD fleet had moderate engine varnish, light sludge and very light lifter rust. The HP fleet had heavy engine varnish, and moderate to light sludge and lifter rust. Medium to heavy wear was observed in the HP units. Both fleets had about the same degree of piston varnish and intake valve deposits. The differences in ratings of the two fleets were attributed to differences in oil drain intervals (SD was less severe) and the higher temperature operation of the HP cars caused by air-conditioning.

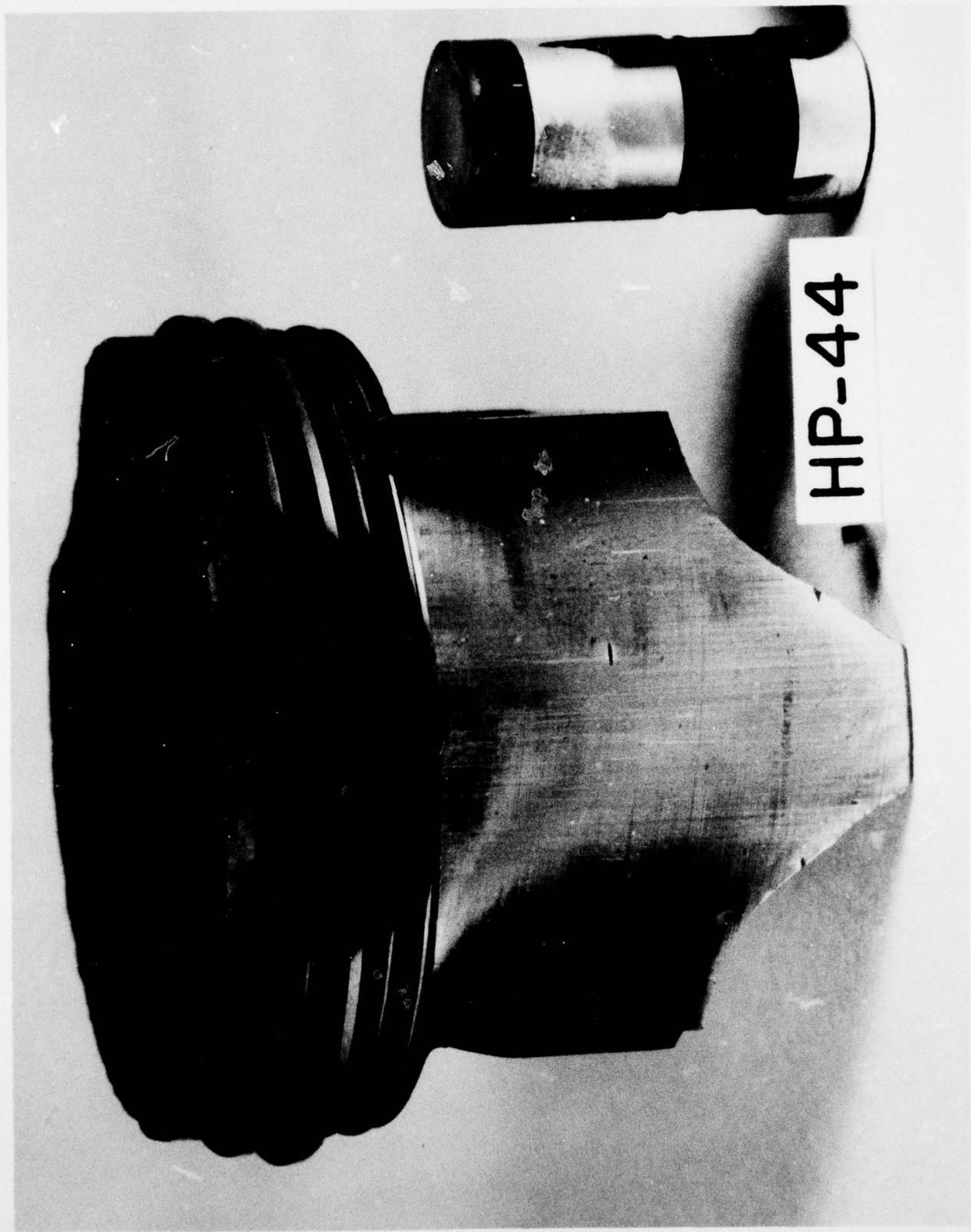
While a number of important variables between the two fleets (e.g., oil drain intervals, air-conditioning, etc.) make *direct comparison* of virgin and rerefined oil performance nearly impossible, the condition of the SD engines after 100,000 miles of using rerefined engine oil was *most encouraging*.

#### Recommendations

Considering the encouraging results of the San Diego engine inspection, it is recommended that:

- (1) A well controlled fleet test (administrative service vehicles) should be conducted at a government installation using a commercially available rerefined engine oil and/or a rerefined oil of the same type as was engine tested in the current program. The test should include a control





HP-44

virgin base lube of MIL-L-46152 quality and similar additive chemistry as the rerefined oil. This fleet test will provide a *direct performance comparison* between rerefined engine oil and a qualified MIL-L-46152 oil in administrative type service.

- (2) Since the Natural Resource Recovery Act (PL-94-580) mandates federal use of recycled products, it is recommended that this engine inspection data be considered by MERADCOM in making the required revision of MIL-L-46152 to cover the use of lubricants formulated from rerefined components.
- (3) It is recommended that baseline data concerning the feasibility of formulating MIL-L-2104C lubricants from rerefined components be developed.

#### Acknowledgement

The author wishes to acknowledge the assistance provided by Mr. T.C. Bowen of USAMERADCOM, Ft. Belvoir, VA. Special recognition is made of Mr. E.R. Lyons who provided the necessary expert deposit ratings.

APPENDIX A

Deposit Ratings (10 = Clean)  
of Individual  
San Diego Engine Parts

## ENGINE INSPECTION

Engine Type: Ford 351C  
 Vehicle ID No.: 4H27H178785  
 Manufacture Date/Body: 3/74 - Torino 4 Dr.  
 Odometer Miles: 96,590  
 Location/Unit No.: San Diego, CA/701  
 Oil Drain/Filter Interval: 4,000 mi.  
 Air Conditioning: No

Sludge Deposits

Rocker Arm Covers	9.2
Intake Manifold	NR
Oil Pan	9.2
Valve Deck Area	9.5
Push Rod Chamber	9.4
Timing Gear Cover	NR
AVG. SLUDGE	9.3

Varnish Deposits

Piston Skirts	5.7
Rocker Arm Covers	6.8
Valve Lifters	6.3
Cylinder Wall (BRT)	8.1
Oil Pan	8.0
AVG. VARNISH	7.0

Additional Ratings

Stuck Valve Lifters	0	Piston Varnish, Max.	6.5
Stuck Compression Rings	0	Piston Varnish, Min.	5.7
Stuck Oil Rings	0	Intake Valve Deposits, Max.	9.0
		Intake Valve Deposits, Min.	6.0
		Intake Valve Deposits, Avg.	7.8

Clogging

Push Rods, No.	0
Oil Ring, %	< 1
Oil Screen, %	< 1

Rust Rating

Valve Lifters	9.8
---------------	-----

Observations, Comments

Valve lifters slightly dished.

Date: 5-77  
 Rater: E.R. Lyons

NR - Not Rated.



## ENGINE INSPECTION

Engine Type: Ford 351C  
 Vehicle ID No.: 4H27H178853  
 Manufacture Date/Body: 3/74 - Torino 4 Dr.  
 Odometer Miles: 91,328  
 Location/Unit No.: San Diego, CA/712  
 Oil Drain/Filter Interval: 4,000 mi.  
 Air Conditioning: No

Sludge Deposits

Rocker Arm Covers	9.2
Intake Manifold	9.5
Oil Pan	9.5
Valve Deck Area	9.5
Push Rod Chamber	9.5
Timing Gear Cover	9.5
AVG. SLUDGE	9.5

Varnish Deposits

Piston Skirts	6.3
Rocker Arm Covers	7.2
Valve Lifters	6.3
Cylinder Wall (BRT)	NR
Oil Pan	7.5
AVG. VARNISH	6.8

Additional Ratings

Stuck Valve Lifters	0	Piston Varnish, Max.	6.6
Stuck Compression Rings	0	Piston Varnish, Min.	5.7
Stuck Oil Rings	0	Intake Valve Deposits, Max.	8.9
		Intake Valve Deposits, Min.	7.5
		Intake Valve Deposits, Avg.	8.0

Clogging

Push Rods, No.	0
Oil Ring, %	<1
Oil Screen, %	<1

Rust Rating

Valve Lifters	9.8
---------------	-----

Observations, Comments

Date: 5-77  
 Rater: E.R. Lyons

NR = Not Rated.

## ENGINE INSPECTION

Engine Type: Ford 351C  
 Vehicle ID No.: 4H27H178864  
 Manufacture Date/Body: 3/74 - Torino 4 Dr.  
 Odometer Miles: 109,703  
 Location/Unit No.: San diego, CA/723  
 Oil Drain/Filter Interval: 4,000 mi.  
 Air Conditioning: No

Sludge Deposits

Rocker Arm Covers	8.9
Intake Manifold	9.5
Oil Pan	9.2
Valve Deck Area	9.2
Push Rod Chamber	9.2
Timing Gear Cover	9.1
AVG. SLUDGE	9.2

Varnish Deposits

Piston Skirts	6.4
Rocker Arm Covers	4.8
Valve Lifters	6.0
Cylinder Wall (BRT)	6.4
Oil Pan	5.0
AVG. VARNISH	5.7

Additional Ratings

Stuck Valve Lifters	0	Piston Varnish, Max.	7.5
Stuck Compression Rings	0	Piston Varnish, Min.	5.8
Stuck Oil Rings	0	Intake Valve Deposits, Max. <sup>a</sup>	9.5
		Intake Valve Deposits, Min. <sup>a</sup>	9.0
		Intake Valve Deposits, Avg. <sup>a</sup>	9.4

Clogging

Push Rods, No.	0
Oil Ring, %	<1
Oil Screen, %	<1

Rust Rating

Valve Lifters	9.8
---------------	-----

Observations, Comments

<sup>a</sup>Reconditioned heads installed at 84,664 miles.

Date: 5-77  
 Rater: E.R. Lyons

## ENGINE INSPECTION

Engine Type:	Ford 351C
Vehicle ID No.:	4H27H178851
Manufacture Date/Body:	3/74 - Torino 4 Dr.
Odometer Miles:	104,514
Location/Unit No.:	San Diego, CA/730
Oil Drain/Filter Interval:	4,000 mi.
Air Conditioning:	No

Sludge Deposits

Rocker Arm Covers	9.3
Intake Manifold	9.5
Oil Pan	9.3
Valve Deck Area	9.3
Push Rod Chamber	9.2
Timing Gear Cover	9.0
AVG. SLUDGE	9.3

Varnish Deposits

Piston Skirts	6.3
Rocker Arm Covers	5.5
Valve Lifters	5.5
Cylinder Wall (BRT)	6.6
Oil Pan	7.5
AVG. VARNISH	6.3

Additional Ratings

Stuck Valve Lifters	0
Stuck Compression Rings	0
Stuck Oil Rings	0

Piston Varnish, Max.	6.8
Piston Varnish, Min.	5.9
Intake Valve Deposits, Max.	9.0
Intake Valve Deposits, Min.	6.0
Intake Valve Deposits, Avg.	8.1

Clogging

Push Rods, No.	0
Oil Ring, %	<1
Oil Screen, %	<1

Rust Rating

Valve Lifters	9.8
---------------	-----

Observations, Comments

Date: 5-77  
 Rater: E.R. Lyons



## ENGINE INSPECTION

Engine Type: Ford 351C  
 Vehicle ID No.: 4H27H178820  
 Manufacture Date/Body: 3/74 - Torino 4 Dr.  
 Odometer Miles: 88,267  
 Location/Unit No.: San Diego, CA/764  
 Oil Drain/Filter Interval: 4,000 mi.  
 Air Conditioning: No

Sludge Deposits

Rocker Arm Covers	9.0
Intake Manifold	9.5
Oil Pan	9.5
Valve Deck Area	9.5
Push Rod Chamber	9.4
Timing Gear Cover	9.0
AVG. SLUDGE	9.3

Varnish Deposits

Piston Skirts	6.3
Rocker Arm Covers	7.3
Valve Lifters	6.7
Cylinder Wall (BRT)	NR
Oil Pan	7.0
AVG. VARNISH	6.8

Additional Ratings

Stuck Valve Lifters	0	Piston Varnish, Max.	6.9
Stuck Compression Rings	0	Piston Varnish, Min.	5.8
Stuck Oil Rings	0	Intake Valve Deposits, Max.	9.5
		Intake Valve Deposits, Min.	7.5
		Intake Valve Deposits, Avg.	9.2

Clogging

Push Rods, No.	0
Oil Ring, %	< 1
Oil Screen, %	< 1

Rust Rating

Valve Lifters	9.8
---------------	-----

Observations, Comments

Date: 6-77  
 Rater: E.R. Lyons

NR = Not Rated.



## ENGINE INSPECTION

Engine Type: Ford 351C  
 Vehicle ID No.: 4H27H178798  
 Manufacture Date/Body: 3/74 - Torino 4 Dr.  
 Odometer Miles: 91,395  
 Location/Unit No.: San Diego, CA/742  
 Oil Drain/Filter Interval: 4,000 mi.  
 Air Conditioning: No

Sludge Deposits

Rocker Arm Covers	9.1
Intake Manifold	9.3
Oil Pan	9.3
Valve Deck Area	9.5
Push Rod Chamber	9.5
Timing Gear Cover	NR
AVG. SLUDGE	9.3

Varnish Deposits

Piston Skirts	6.0
Rocker Arm Covers	5.6
Valve Lifters	5.7
Cylinder Wall (BRT)	6.8
Oil Pan	7.0
AVG. VARNISH	6.2

Additional Ratings

Stuck Valve Lifters	0
Stuck Compression Rings	0
Stuck Oil Rings	0

Piston Varnish, Max.	6.3
Piston Varnish, Min.	5.7
Intake Valve Deposits, Max.	9.0
Intake Valve Deposits, Min.	6.5
Intake Valve Deposits, Avg.	8.1

Clogging

Push Rods, No.	0
Oil Ring, %	< 1
Oil Screen, %	< 1

Rust Rating

Valve Lifters	9.8
---------------	-----

Observations, Comments

Date: 6-77  
 Rater: E.R. Lyons

NR = Not Rated.

APPENDIX B

Deposit Ratings (10 = clean)  
of Individual  
Hollywood Park Engine Parts

## ENGINE INSPECTION

Engine Type: Ford 351C  
 Vehicle ID No.: 4H27Q223207  
 Manufacture Date/Body: 7/74 - Torino 4 Dr.  
 Odometer Miles: 71,847  
 Location/Unit No.: Hollywood Park, TX/44  
 Oil Drain/Filter Interval: 6,000 mi.  
 Air Conditioning: Yes

Sludge Deposits

Rocker Arm Covers	NR
Intake Manifold	8.0
Oil Pan	9.0
Valve Deck Area	8.4
Push Rod Chamber	9.0
Timing Gear Cover	9.0
AVG. SLUDGE	8.7

Varnish Deposits

Piston Skirts	6.0
Rocker Arm Covers	NR
Valve Lifters	2.0
Cylinder Wall (BRT)	5.4
Oil Pan	5.0
AVG. VARNISH	4.6

Additional Ratings

Stuck Valve Lifters	0	Piston Varnish, Max.	6.2
Stuck Compression Rings	0	Piston Varnish, Min.	5.6
Stuck Oil Rings	0	Intake Valve Deposits, Max.	9.0
		Intake Valve Deposits, Min.	8.5
		Intake Valve Deposits, Avg.	8.7

Clogging

Push Rods, No.	0
Oil Ring, %	<1
Oil Screen, %	<1

Rust Rating

Valve Lifters	8.8
---------------	-----

Observations, Comments

Main and connecting rod bearings have medium to heavy wear.  
 Valve lifters are dished.

Date: 7-77  
 Rater: E.R. Lyons

NR = Not Rated.



## ENGINE INSPECTION

Engine Type: Ford 351C  
 Vehicle ID No.: 4H27Q223208  
 Manufacture Date/Body: 7/74 - Torino 4 Dr.  
 Odometer Miles: 65,488  
 Location/Unit No.: Hollywood Park, TX/45  
 Oil Drain/Filter Interval: 6,000 mi.  
 Air Conditioning: Yes

Sludge Deposits

Rocker Arm Covers	8.1
Intake Manifold	7.6
Oil Pan	9.4
Valve Deck Area	8.6
Push Rod Chamber	9.0
Timing Gear Cover	9.0
AVG. SLUDGE	8.6

Varnish Deposits

Piston Skirts	6.6
Rocker Arm Covers	2.0
Valve Lifters	2.5
Cylinder Wall (BRT)	5.8
Oil Pan	4.5
AVG. VARNISH	4.3

Additional Ratings

Stuck Valve Lifters	0
Stuck Compression Rings	0
Stuck Oil Rings	0

Piston Varnish, Max.	6.7
Piston Varnish, Min.	6.0
Intake Valve Deposits, Max.	8.0
Intake Valve Deposits, Min.	7.0
Intake Valve Deposits, Avg.	8.0

Clogging

Push Rods, No.	0
Oil Ring, %	<1
Oil Screen, %	<1

Rust Rating

Valve Lifters	9.0
---------------	-----

Observations, Comments

Main and connecting rod bearings have medium to heavy wear.  
 Valve lifters are dished.

Date: 7-77  
 Rater: E.R. Lyons

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